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RECORDS OF AUSTRALIAN FOULING ORGANISMS: SESSILE BARNACLES (CRU--ETC(U))
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REPORT

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SESSILE BARNACLES (CRUSTACEA, CIRRIPEDIA)

John A. Lewis

THE COMMONWEALTH OF AUSTRALIA
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Ten species of barnacle collected during studies on marine fouling at Defence exposure sites in Queensland, New South Wales, Victoria and Western Australia are described and illustrated. Morphological and systematic characters of balanomorph barnacles are described and a taxonomic key presented to enable these important fouling organisms to be routinely identified.

The report complements earlier manuals on Australian marine fouling and extends their geographic range.

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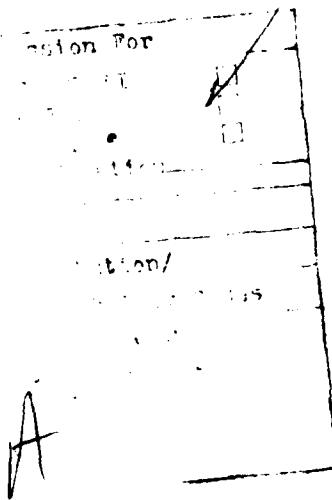
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RECORDS OF AUSTRALIAN FOULING ORGANISMS:
SESSILE BARNACLES (CRUSTACEA, CIRRIPEDIA)

1. INTRODUCTION

Published manuals on the marine fouling organisms in Australian waters have been largely restricted to those species frequently encountered around the major Naval dockyards in south-east Australia (Ferguson Wood & Allen, 1958; Russ & Wake, 1975). Recent studies of marine fouling in northern Queensland (Lewis, 1979) and Western Australia (Dunstan, 1978) have reported many species not included in the earlier manuals. To enable the routine identification of fouling species from these sites, reports are planned on each of the major groups of fouling organisms. This report is the first in the series and describes the sessile barnacles.

Specimens described were collected from the five sites where Defence facilities are currently available for the exposure and testing of materials (Fig. 1). A list of the ten species discussed in this report, together with their collection sites, is given in Table 1. Nomenclature is based on the recent revision of the balanomorph barnacles by Newman and Ross (1976).

2. MORPHOLOGICAL AND SYSTEMATIC CHARACTERS

The soft body of a balanomorph barnacle is enclosed within a shell of separable calcareous plates (Figure 2a). Fixed wall plates encircle the animal and two pairs of opercular plates cover the aperture. The opercular plates are retracted when the animal feeds. Each wall plate has a central triangular section; the paries (plural: parietes), and wing-like extensions termed *radii* if they overlap, or *alae* if they underlie the adjacent wall plates (Figure 2a). The upper section on the interior surface of the parietes is thickened in some barnacle species; this region is called the sheath (Figure 2e). The carina and the rostrum are the wall plates at the posterodorsal and anteroventral ends of the animal respectively. The paired

	Garden Is., W.A.	Williamstown, Vic.	Garden Is., N.S.W.	Clump Pt., Qld.	Nth Barnard Is., Qld.
<i>Cthamalus malayensis</i>			+		+
<i>Austrobalanus imperator</i>			+	++	++
<i>Tetraclita coerulescens</i>			+		+++
<i>Chirona amaryllis</i>			+++	+	
<i>Elminius modestus</i>		++			
<i>Acasta dofleini</i>				+	
<i>Balanus amphitrite</i>	+	+	++		++
<i>Balanus reticulatus</i>					
<i>Balanus variegatus</i>	++	++	+++		
<i>Balanus trigonus</i>	+++				

TABLE 1 Occurrence of barnacle species at each of the study sites

(+, present; ++ common; +++ dominant barnacle species at site)

plates are named from their positions relative to the rostrum and the carina; i.e. carino-lateral, lateral, rostrolateral (Figures 2a, 2b). Plate terminology is based on a barnacle with eight wall plates. Genera with lesser numbers of plates are considered to be derived from an eight-plated ancestor through loss or fusion of plates (see Newman and Ross, 1976) and remaining plates are named accordingly.

The pair of opercular plates closest to the rostrum are the scutae whilst those closest to the carina are tergae (Figure 2b). The internal surfaces of these plates have characteristic ridges and pits for the attachment of the retractor muscles (Figures 2c, d). A calcareous or membranous disc, called the basis, forms the floor of the shell (Figure 2e).

Most genera and many species of barnacle can be identified from features of the shell. However some species can only be identified after examination of the soft body components; in particular, the feeding appendages (cirri) and the mouthparts (trophi). Six pairs of cirri lie behind the mouth (Figure 2e). The cirri vary in length and are covered in spines and hairs which permit the gathering and manipulation of food to the mouth. The mouthparts comprise a lower lip (*labrum*), a pair of crushing jaws (*mandibles*) and three further pairs of appendages (*mandibular palps*, *first maxillae*, *second maxillae*) to assist in food manipulation

3. KEY TO SPECIES

1. 4 wallplates (Figure 3b, e)2
1. 6 wallplates3
2. Wallplates with several rows of internal tubes (Figure 6f)

Tetraclita coerulescens
2. Wallplates solid Elminius modestus
3. Embedded in sponge; wallplates with calcareous spines (Plate 2e,f)

Acasta dofleini
3. Not as above4
4. Rostrum with two alae (Figure 3a) Chthamalus malayensis
4. Rostrum with two radii5
5. Wallplates strongly ribbed6
5. Wallplates externally smooth7

6. Outer surface of scutae pitted (Figure 5d); interior of shell white
Balanus trigonus
6. Scutae smooth (Figure 5a); interior of shell deep purple
Austrobalanus imperator
7. Outer surface of scutae beaded (Figure 5b)
Chirona amaryllis
7. Scutae not beaded8
8. Spur on tergum wider than long (Figure 4e); labrum multidenticulate
(Plate 4e) *Balanus amphitrite amphitrite*
8. Spur on tergum longer than wide (Figure 5c, e); labrum simple
(Plate 4f)9
9. Parietes externally cross hatched with longitudinal and transverse coloured bands (Plate 4a,b); in some specimens basal margin of tergum deeply excavated on either side of spur (Figure 5c).
Balanus variegatus
9. Parietes with only longitudinal bands of colour (Plate 3c-f); basal margin of tergum always straight (Figure 5e).
Balanus reticulatus

4. DESCRIPTION OF SPECIES

4.1 Genus Chthamalus Ranzani, 1817

Generic features: 6 shell plates; rostrum with two alae (Figure 3a)

Chthamalus malayensis Pilsbry, 1916
Figure 4a; Plate 1a, b

Species description: Pope 1965:51, text figs 11, 5a-g; plate 2 figs 3, 6-7.

Specific features: Shell shaped like a truncated cone, parietes ribbed in uneroded specimens (Plate 1a, b). Scutum with deep lateral depressor muscle pit; tergum with at least 3 depressor muscle crests (Figure 4a).

Distribution: Indo-Malaysian region; in Australia along the northern

coastline from Hervey Bay in the east to Garden Island in the south west (Pope, 1965).

Comments: This small species is generally found on rocks in the upper half of the intertidal zone but has also been recorded on mangroves and wharf piles (Pope, 1965). The few specimens collected in the present study were collected on panels at the North Barnard Islands and Clump Point. All were juvenile specimens.

Of the other Australian representatives of this genus, *C. malayensis* is closest to *C. antennatus* Darwin. However, the latter species has a temperate distribution (from Bustard Head in Queensland, around the south-east coastline to Eucla in Western Australia) and has only two, or rarely three, depressor muscle crests on the tergum. Other Australian *Chthamalus* species have flattened shells without distinct ribs and only three teeth on the mandible compared with 4 or 5 in *C. malayensis* (see Pope, 1965).

Collection sites: Clump Point, North Barnard Islands.

4.2 Genus *Austrobalanus* Pilsbry, 1916

Generic features: 6 shell plates; solid parietes (Figure 6c); rostrum with two radii; carino-lateral plates narrow (Figure 3c)

Austrobalanus imperator (Darwin, 1854)
Figures 5a, 6c; Plate 1c, d.

Species description: Darwin 1854:288, plate 8 fig 4a-c (as *Balanus imperator*); Pope 1945:364, plate 28 fig. 8, 10, plate 30 figs. 11-12 (as *Balanus (Austrobalanus) imperator*).

Specific features: Shell plates thick and strongly ribbed (Plate 1c, d), whitish externally but internally deep purple; radii poorly developed. Basis calcareous but very thin; superficially appearing membranous. Opercular plates externally smooth; scutum with sharply-pointed apex, crests for attachment of depressor muscles present at rostral and basitergal corners; tergum with rounded spur, articular ridge well developed, depressor muscle crests prominent. (Figure 5a).

Distribution: Endemic, northern coastline extending south to Port Jackson in the east.

Comments: *Austrobalanus imperator* has a sporadic distribution on islands throughout Queensland waters and is suspected to be essentially a sublittoral species (Endean, Stephenson & Kenny, 1956). The rugged sculpturing of the shell plates and the purple coloration of the internal shell walls make *A. imperator* a very distinctive species.

Collection sites: Clump Point, North Barnard Islands.

4.3 Genus Tetraclitia Schumacher, 1817

Generic features: 4 shell plates; rostrum with two radii (Figure 3b); parietes permeated by several rows of longitudinal tubes (Figure 6f); radii solid with oblique summits.

Tetraclitia coerulescens (Spengler, 1790)
Figures 4b, 6f; Plate 1e, f.

Species description: Darwin 1854:342, plate 11 fig. 4a-d; Broch 1931:116.

Specific features: Parietes longitudinally ribbed, white or pinkish with summits tinged greenish blue (Plate 1e, f). Articular ridge on scutum pronounced and united with adductor ridge; tergum with spur not confluent with basiscutal angle (Figure 4b).

Distribution: Indo-Malaysian region; in Australia possible widespread in tropical waters.

Comments: *Tetraclitia coerulescens* is reported to be the only fouling species of the genus (Daniel, 1972). Observations at the North Barnard Islands support this contention as only *T. coerulescens* was collected on panels although both *T. squamosa* (Bruguiere) and *T. vitiata* Darwin also grow on rocks in the region (Endean, Stephenson & Kenny, 1956). *T. coerulescens* differs from other species of *Tetraclitia* in the colour of the shell and features of the opercular plates.

Collection sites: Clump Point, North Barnard Islands.

4.4 Genus Chirona Gray, 1835

Generic features: 6 shell plates, parietes and radii thin and solid (Figure 6d); margins of radii smooth or with minute teeth; rostrum with two radii.

Chirona amaryllis (Darwin, 1854)
Figures 5b, 6d; Plate 2a, b.

Species description: Darwin 1854:279, plate 7, figs. 6a-c, Pope 1945:364, plate 28 fig. 7, plate 30 figs. 17-20 (both as *Balanus amaryllis*).

Specific features: Shell moderately large; tubulo-conic, carinal margin of orifice spoutlike (Plate 2a, b); parietes solid (Figure 6d), externally smooth, white to pinkish with narrow pink or brownish longitudinal grooves and transverse growth lines giving a beaded texture; tergum with apex recurved toward scutum, spur long and narrow, a furrow on the outer surface extends to the apex along the line of the spur (Figure 5b).

Distribution: Indo-Malaysian region, China, Japan; northern Australia extending south to at least Port Jackson in the east.

Comments: *Chirona amaryllis* is essentially a subtidal species and has been recorded from the surface to depths of 500 m (Stubblings, 1936; Daniel, 1972). In Queensland the distribution of the species extends into the lower intertidal zone (Endean, Kenny & Stephenson, 1956) but in Port Jackson all records are subtidal (Pope, 1945).

Young individuals of *C. amaryllis* can outwardly resemble *Balanus amphitrite amphitrite* and *B. reticulatus*. However, *C. amaryllis* can be readily distinguished by the beaded texture of the scutum (Figure 5b) and the solid parietes (Figure 6d).

Collection sites: Clump Point, North Barnard Islands.

4.5 Genus Elminius Leach, 1825

Generic features: 4 loosely-joined shell plates (Figure 3e), parietes solid, rostrum with two radii, labrum deeply notched.

Elminius modestus Darwin, 1854
Figure 4c; Plate 2c, d.

Species description: Foster 1978:95, fig. 57, plate 12c.

Specific features: Shell white or grey, parietes ribbed longitudinally (Plate 2c, d), basis membranous. Scutum externally with two longitudinal dark bands, internally with articular ridge moderately developed but adductor ridge poorly developed or absent; tergum with spur confluent with basiscutal corner, basal margin concave (Figure 4c).

Distribution: Southern Australia, New Zealand; introduced via shipping to the Atlantic coasts of Europe.

Comments: *Elminius modestus* is a small barnacle which settles in large numbers on wharf pilings and mangroves during early summer. The species was introduced to Europe via ship fouling at the beginning of the Second World War and has since been spreading along the Atlantic shores (Southward & Crisp, 1963). *E. modestus* does occur on sheltered shores around Sydney; however, Pope's (1945) description and illustrations of *E. modestus* refer to another, yet to be published, species of this genus (Foster, pers. comm.). *E. modestus* has less color and fewer longitudinal ribs on the parietes than the new species.

Collection sites: Williamstown.

4.6 Genus Acasta Leach, 1817

Generic features: Six thin shell plates (Figure 3f); living embedded in sponges and coelenterates.

Acasta dofleini Krüger, 1911
Figures 4d, Plate 2e, f.

Species description: Nilsson-Cantell 1921:341; Rosell 1972:198, plate 23 figs. 3-4, plate 25 figs. 1-8.

Specific features: Shell globose, white; parietes, with the exception of the carino-lateral plate, externally furnished with many calcareous processes, each process overlying a pore (Plate 2e, f); carino-lateral plate reduced to only a radius and ala, with pointed base barely reaching the basis; interior of parietes with faint longitudinal ribs, basis flat, slightly toothed around margin. Scutum triangular with poorly developed adductor ridge and muscle pits; tergum with apex recurved toward scutum, spur not confluent with basiscutal angle (Figure 4d). Embedded in encrusting sponge.

Distribution: Northern Australia, southern Japan, Indonesia, Sulu Archipelago.

Comments: *Acasta dofleini* is one of the few species of *Acasta* in which the carino-lateral plates are reduced to little more than a radius and ala. Early descriptions of *A. dofleini* make no mention of the spines on the parietes, but descriptions were based on empty shells or poorly preserved material (Krüger, 1911; Nilsson-Cantell, 1921). Later authors describe the presence of the spines (Broch 1931; Rosell, 1972). A. zuiho Hiro (1936:632), figs. 8, 9, collected near Darwin and only reported from that locality, appears from the description to be *A. dofleini*.

A. dofleini is a small species with the largest specimens examined only 5 mm in diameter.

Collection sites: North Barnard Islands.

4.7 Genus *Balanus* da Costa, 1778

Generic features: 6 shell plates; parietes with internal tubes, radii solid; rostrum with two radii (Figure 3d).

a. *Balanus amphitrite amphitrite* Darwin, 1854
Figure 4e, Plates 3a, b, 4e.

Species description: Henry & McLaughlin 1975:30, text figs. 10-11, 13, plates 1a-j, 5g, 9b, c.

Specific features: Shell white with light brown or mauve longitudinal stripes (Plate 3a, b); parietes externally smooth with a single row of internal tubes (cf. Figure 6e). Scutum with articular ridge 3/5 the length of the tergal margin, adductor ridge separated from articular ridge; tergum with upper 1/3 to 1/2 protruding, spur wider than long, less than own width from basiscutal angle (Figure 4e). Labrum multidenticulate (Plate 4e).

Distribution: Widespread in tropical and temperate waters.

Comments: Of the species discussed in this report, *Balanus amphitrite amphitrite* is superficially most similar to *B. reticulatus*. The most reliable criterion for separating the two species is the nature of the labrum; simple in *B. reticulatus*, multidenticulate in *B. a. amphitrite* (Plate 3a, b). However, the shape of the tergum also differs. In *B. a. amphitrite* the distance from the spur to the basiscutal angle is narrower than the width of the spur, whilst in *B. reticulatus* it is approximately equal (cf. Figures 4e, 5e). In addition the spur is generally wider than long in *B. a. amphitrite* and longer than wide in *B. reticulatus*.

B. improvisus Darwin, which has a multidenticulate labrum similar to *B. a. amphitrite*, has also been reported from Australian waters (Bishop, 1951). *B. improvisus* can be distinguished from *B. a. amphitrite* by the presence of a furrow on the outer surface of the tergum in line with the spur.

The following species and varieties recorded in Australian publications on marine fouling are synonymous with *B. a. amphitrite*:

B. amphitrite var. *communis Darwin* (Pope, 1945; Ferguson Wood and Allen, 1958)

B. variegatus var. *communis Darwin* (Russ, 1977)

Collection sites: Cockburn Sound, Williamstown, Garden Island (NSW).

b. *Balanus reticulatus Utinomi*, 1967
Figures 5e, 6b, e; Plates 3c-f, 4f.

Species description: Henry & McLaughlin 1975:88, text figs. 11, 18, plates 7d, 8a-d, 9a, d, e.

Specific features: Shell white with light brown, mauve or pinkish longitudinal stripes (Plate 3c-f); parietes externally smooth with a single row of internal tubes (Figure 6e), summits of radii bevelled; purple longitudinal band on inner surface of alae. Scutum with articular ridge 2/3 the length of the tergal margin; tergum with spur longer than wide, distance from basiscutal angle to spur approximately equal to spur width (Figure 5e). Labrum simple (Plate 4f).

Distribution: Cosmopolitan in tropical waters.

Comments: Two distinct colour forms of *Balanus reticulatus* often coexist on panels from the North Barnard Islands, with intermediate colour forms sometimes present. One form has a predominantly white to buff-coloured shell with brown longitudinal stripes (Plate 3c, d). The distance between the stripes is wider than the stripes themselves and stripes are often absent from the margin and mid-section of the parietes. The opercular plates are predominantly white with brown longitudinal bands of colour on the external surface. The shell of the second colour form has a pinkish hue (Plate 3e, f). Purplish-brown longitudinal stripes extend over the full width of the parietes and are almost confluent. Internal and external surfaces of the opercular plates are purplish brown with white margins. The external colour

of the alae and radii in both forms is white or brownish. Both forms agree in morphological and anatomical detail.

B. amphitrite, sensu Lewis (1979), from the North Barnard Islands is referable to *B. reticulatus*. Differences between *B. reticulatus* and the superficially similar *B. amphitrite amphitrite* were discussed under the latter species.

Collection sites: North Barnard Islands.

c. *Balanus variegatus* Darwin, 1854
Figures 5c, 6a; Plate 4a, b.

Species description: Foster 1978:111, fig. 67, plate 14b.

Specific features: Shell conic to tubular; parietes externally smooth, off-white, cross-hatched by longitudinal and transverse purple bands (Plate 4a, b), with a single row of internal tubes (as in Figure 6e); radii white or pink; sheath vesicular (Figure 6a), purple with white bands on lateral plates. Scutum externally with two radiating purple bands, growth lines prominent, articular ridge 3/5 the length of the tergal margin; tergum externally purple with white margins, spur and line from spur to apex, basal margin, straight or deeply excavated on either side of spur, inner surface sometimes projecting below basal margin and visible from exterior, spur pointed, longer than wide, distance from spur to basiscutal angle greater than spur width (Figure 5c). Labrum simple.

Distribution: Australia, New Zealand.

Comments: *Balanus variegatus* was originally described as a variety of *B. amphitrite* (Darwin, 1854). However, the forms and varieties of *B. amphitrite* and its closely related species have not, until recently, been clearly defined. The assigning of the present material to *B. variegatus*, although not consistent with the redescription of this taxon in Henry and McLaughlin's (1975) monograph on the *Balanus amphitrite* complex, is based on examination of specimens from the type locality (Sydney), as designated by Harding (1962), and is consistent with his description of the species.

B. variegatus can be distinguished from other *Balanus* species discussed in this report by the cross-hatched colouration of the shell and the shape of the opercular plates. The shell often assumes a tubular form when growing in dense colonies.

The following species and varieties recorded from Australia are considered synonymous with *B. variegatus*:

B. amphitrite var. *cirratus* Darwin (Pope, 1945; Ferguson Wood and Allen, 1958).

B. variegatus var. *cirratus* Darwin (Russ and Wake, 1975; Russ, 1977).

B. amphitrite var. *stutsburi* Darwin (Krüger, 1974)

Collection sites: Cockburn Sound, Williamstown, Garden Island (NSW).

d. *Balanus trigonus* Darwin, 1854
Figure 5d; Plate 4c, d.

Species description: Foster 1978:113, fig. 68, plate 14c.

Specific features: Shell conical, depressed; radii wide; parietes pinkish with raised longitudinal ribs (Plate 4c, d) and a single row of internal tubes; shell interior white. Scutum with longitudinal furrows intersected by transverse growth ridges to form rows of pits on the outer surface; tergum with wide blunt spur, 1/2 to 1/3 the length of the basal margin (Figure 5d).

Distribution: Cosmopolitan in warm seas.

Comments: *Balanus trigonus* was the most abundant barnacle on test panels and wharf pilings at HMAS Stirling. Pope (1945) reports the species as predominantly subtidal in Port Jackson.

The pitted surface of the scutum clearly separates *B. trigonus* from the other species of *Balanus* in this report.

Collection Sites: Cockburn Sound.

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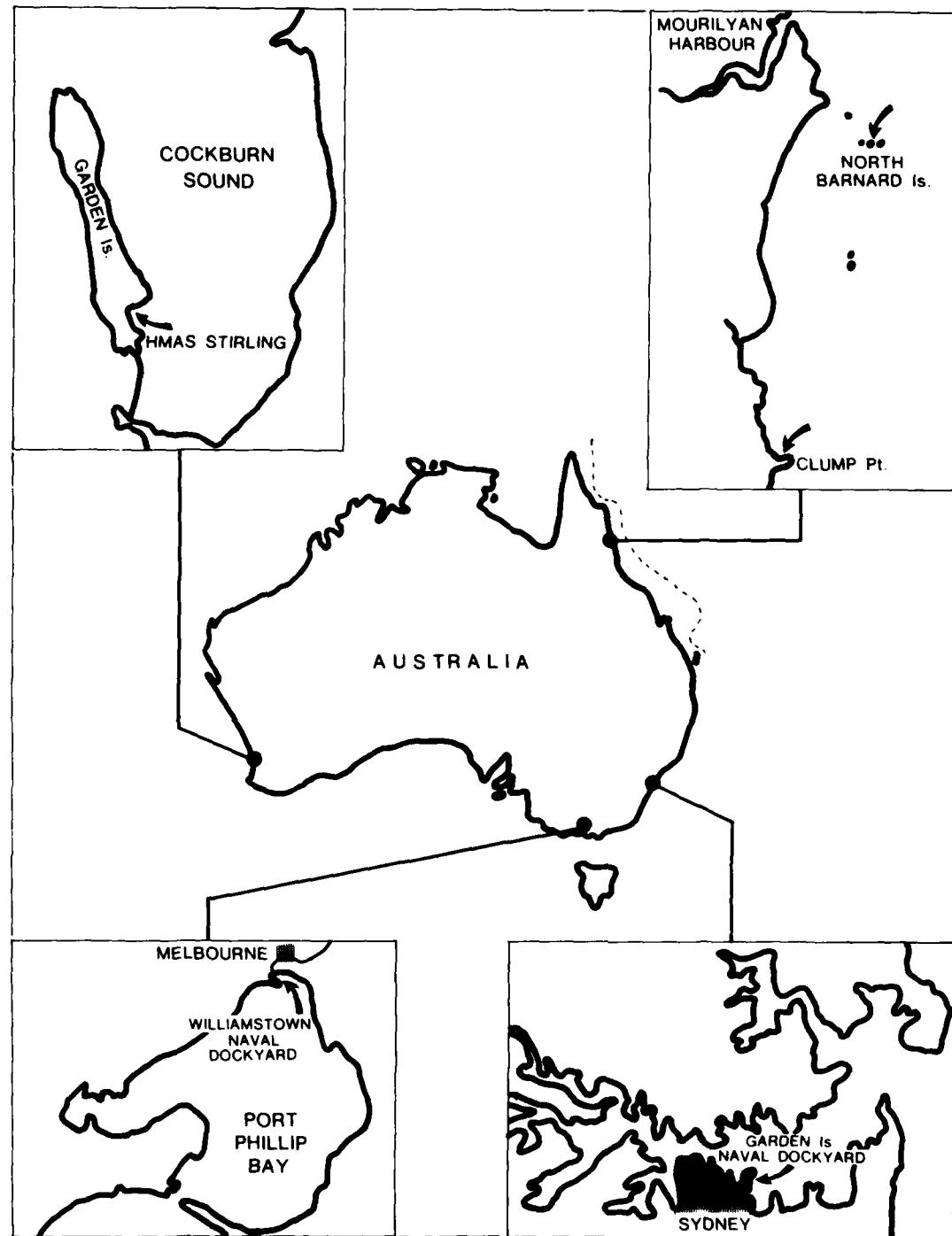
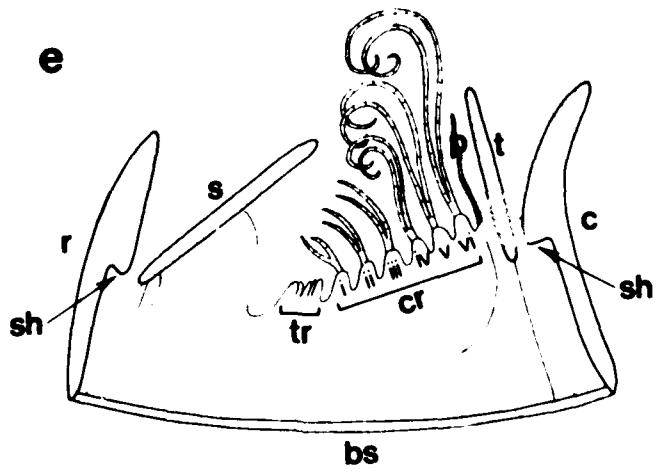
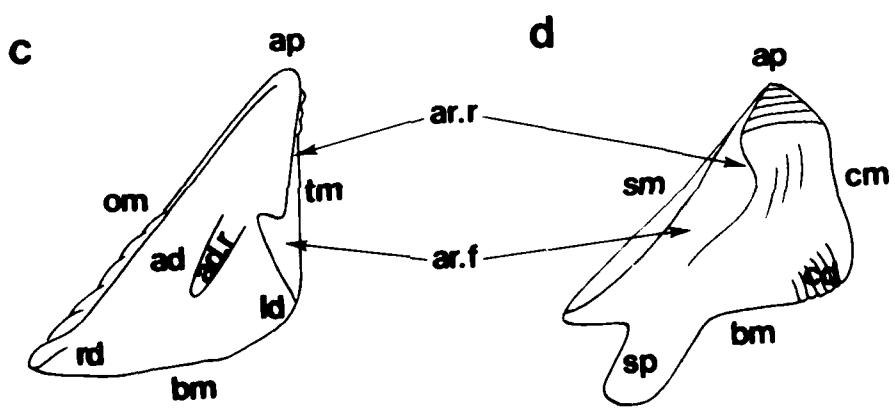
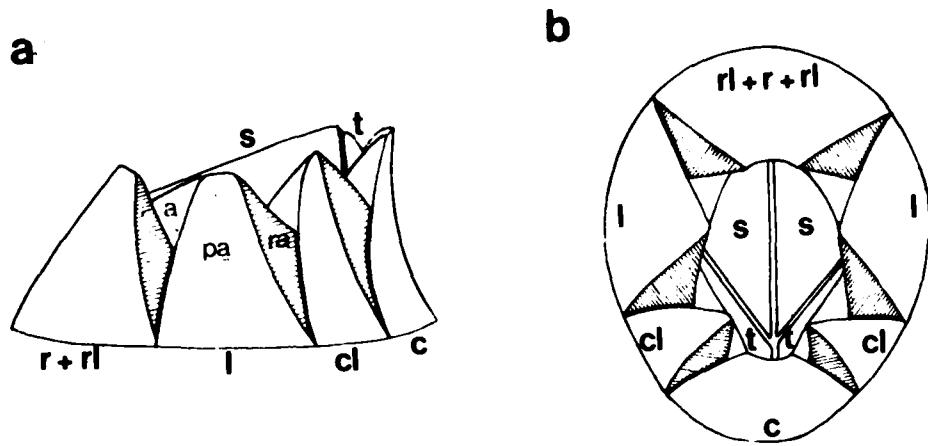


FIGURE 1 Marine immersion sites where fouling studies were undertaken (North Barnard Island and Clump Pt. sites operated by the Joint Tropical Trials and Research Establishment, Innisfail).

FIGURE 2 Morphological features of balanomorph barnacles. a, b entire shell (a, side view; b, surface view) c, d interior of opercular plates (c, scutum; d, tergum) e section to show body components.

(a, ala; ad adductor muscle pit; ad.r adductor ridge; ap apex; ar.f articular furrow; ar.r articular ridge; bm basal margin; bs basis; c carina; cd depressor muscle crests; cl carino-lateral plate; cm carinal margin; cr cirri; l lateral plate; ld lateral depressor muscle pit; om occuludent margin; p penis; pa paries; r rostrum; rd rostral depressor muscle pit; rl rostro-lateral plate; s scutum; sm scutal margin; sp tergal spur; t tergum; tm tergal margin; tr trophi).



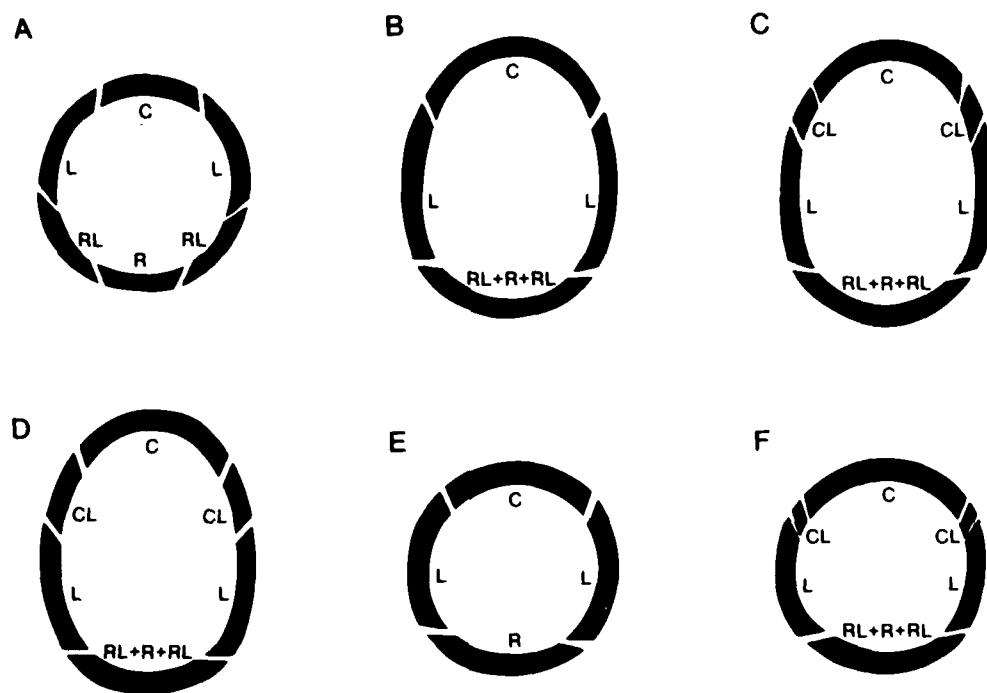
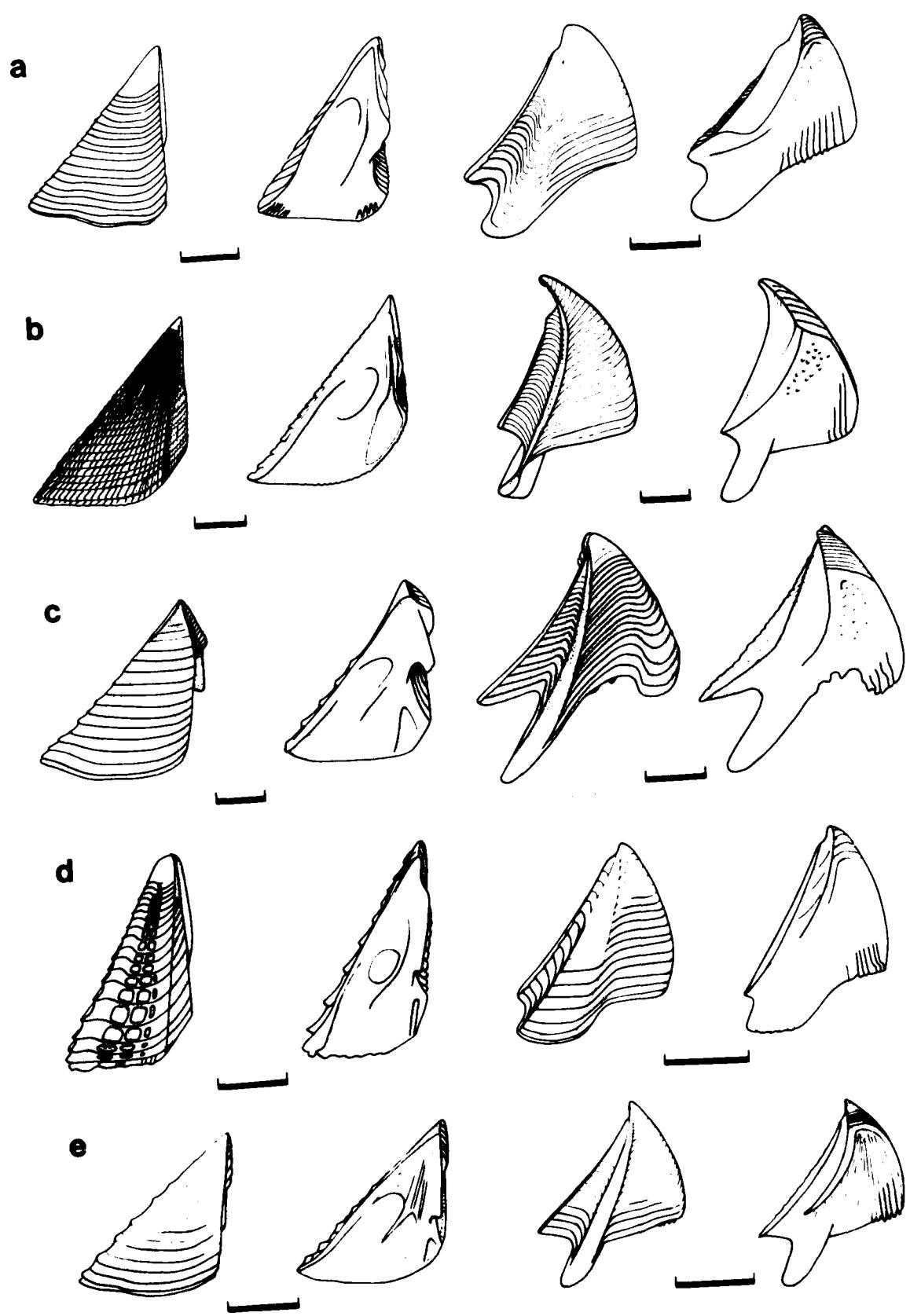


FIGURE 3 Arrangement of wall plates in the genera studied
 a. *Chthamalus* b. *Tetraclita* c. *Austrobalanus*
 c. *Balanus*, *Chirona* e. *Elminius* f. *Acasta*

FIGURE 4 Opercular plates. (left to right: scutum exterior, scutum interior, tergum exterior, tergum interior)

- a. *Chthamalus malayensis*
- b. *Tetraclita coeruleescens*
- c. *Elminius modestus*
- d. *Acasta dofleini*
- e. *Balanus amphitrite amphitrite*

(Scale bars = 2 mm)



**FIGURE 5 Opercular plates. (left to right: scutum exterior,
scutum interior, tergum exterior, tergum interior)**

- | | |
|-----------------------------------|-----------------------------|
| a. <i>Austrobalanus imperator</i> | b. <i>Chirona amaryllis</i> |
| c. <i>Balanus variegatus</i> | d. <i>Balanus trigonus</i> |
| e. <i>Balanus reticulatus</i> | |

(Scale bars = 2 mm)

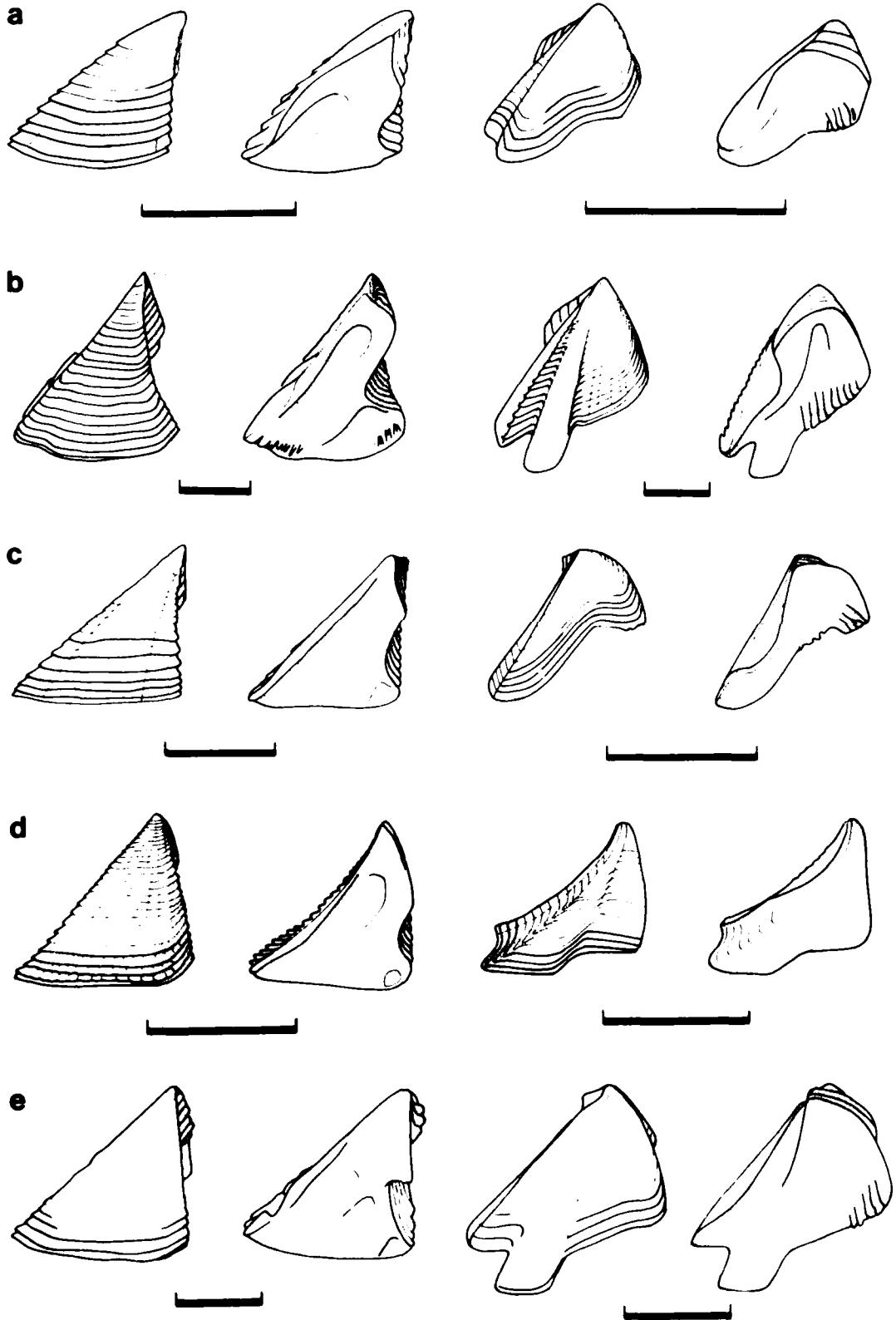
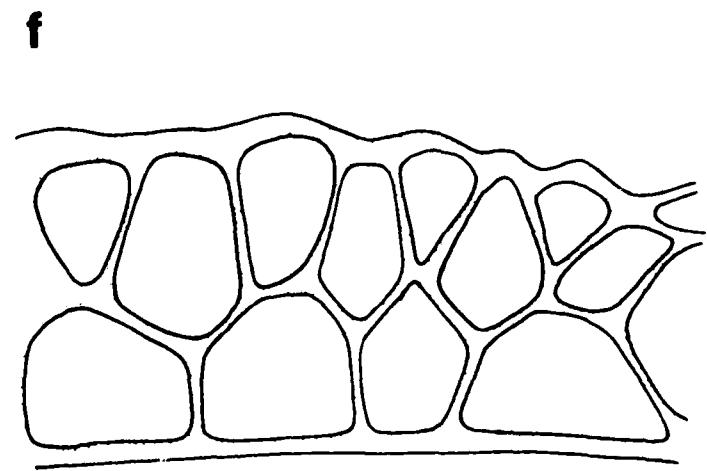
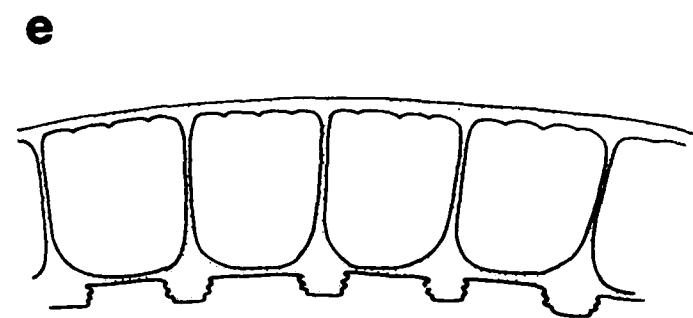
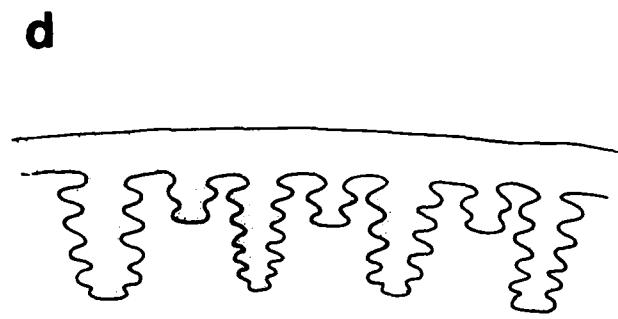
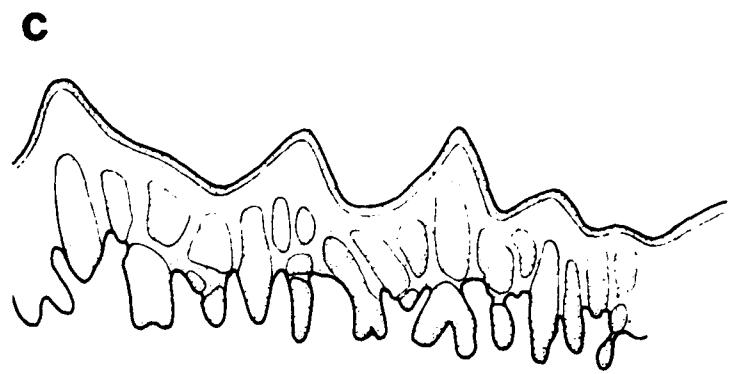
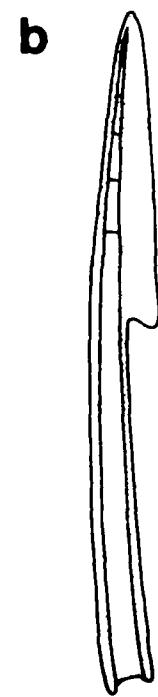
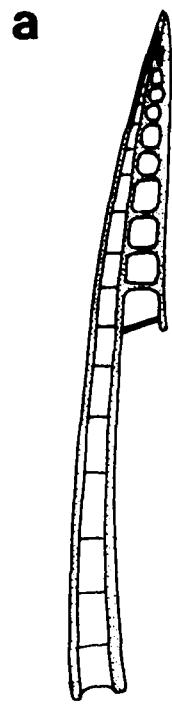


FIGURE 6 a, b Section through paries to show structure of sheath
(a. *B. variegatus*, vesicular; b. *B. reticulatus*, solid)
c-f Lower edge of paries to show wall structure
c. solid, *A. imperator* d. solid, *C. amaryllis*
e. single row of tubes, *B. reticulatus*
f. several rows of tubes, *T. coeruleascens*



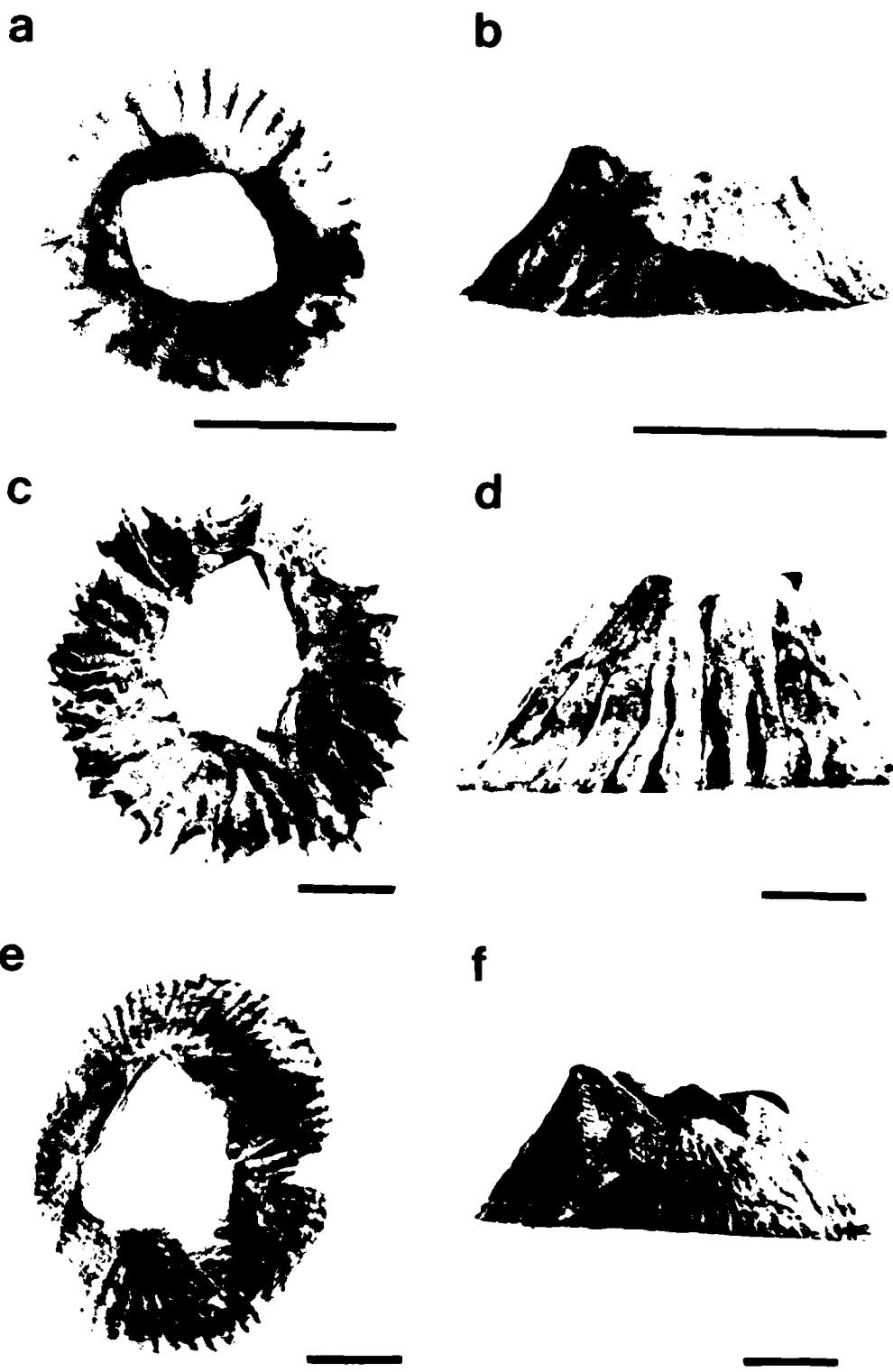


PLATE 1 Surface and lateral view of outer shells
 a, b. *Chthamalus malayensis*
 c, d. *Austrobalanus imperator*
 e, f. *Tetraclita coerulescens*
 (Scale bars = 5 mm)

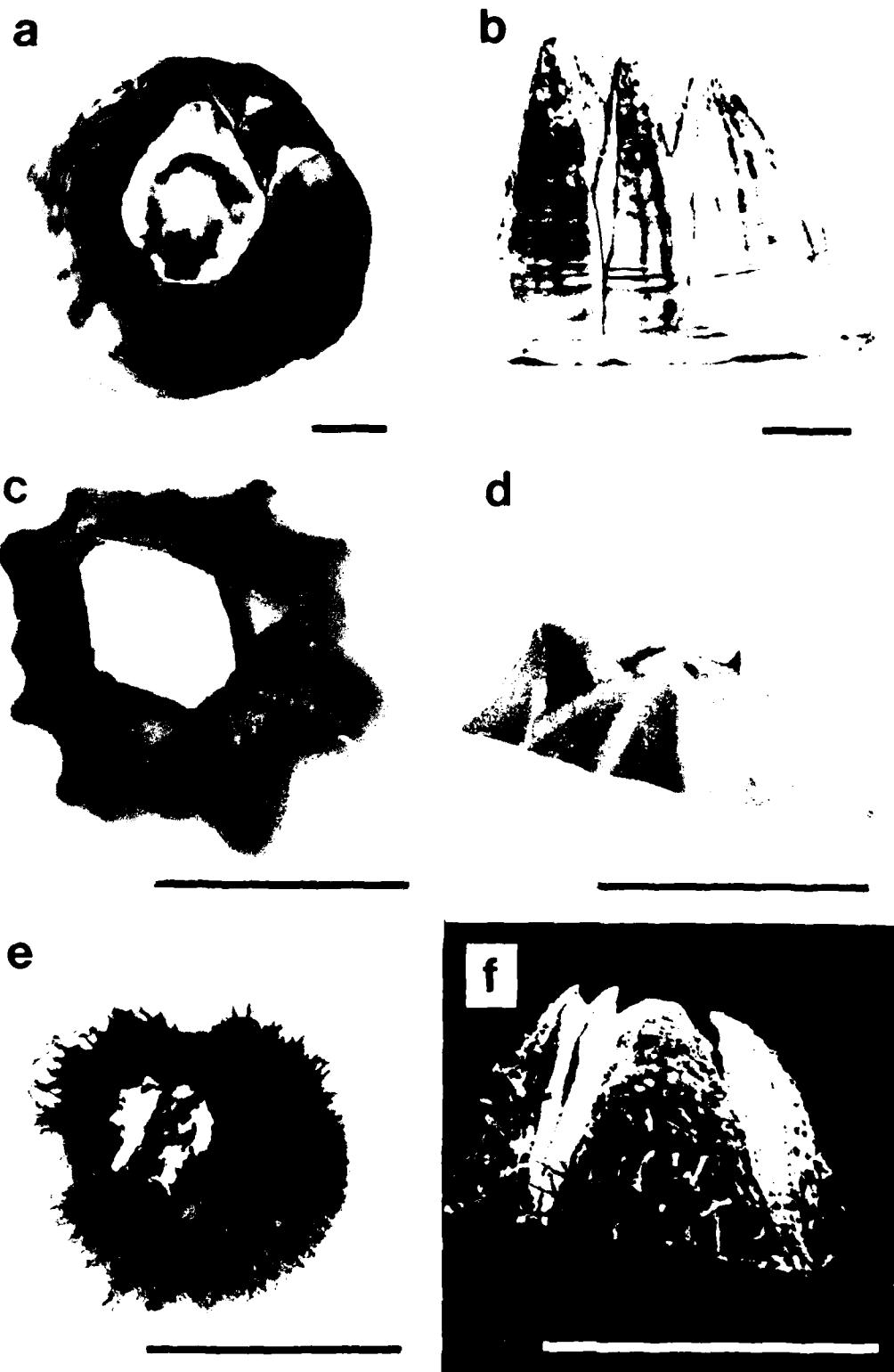


PLATE 2 Surface and lateral view of outer shells
 a, b. *Chirona amaryllis*
 c, d. *Elminius modestus*
 e, f. *Acasta dofleini*
 (Scale bars = 5 mm)

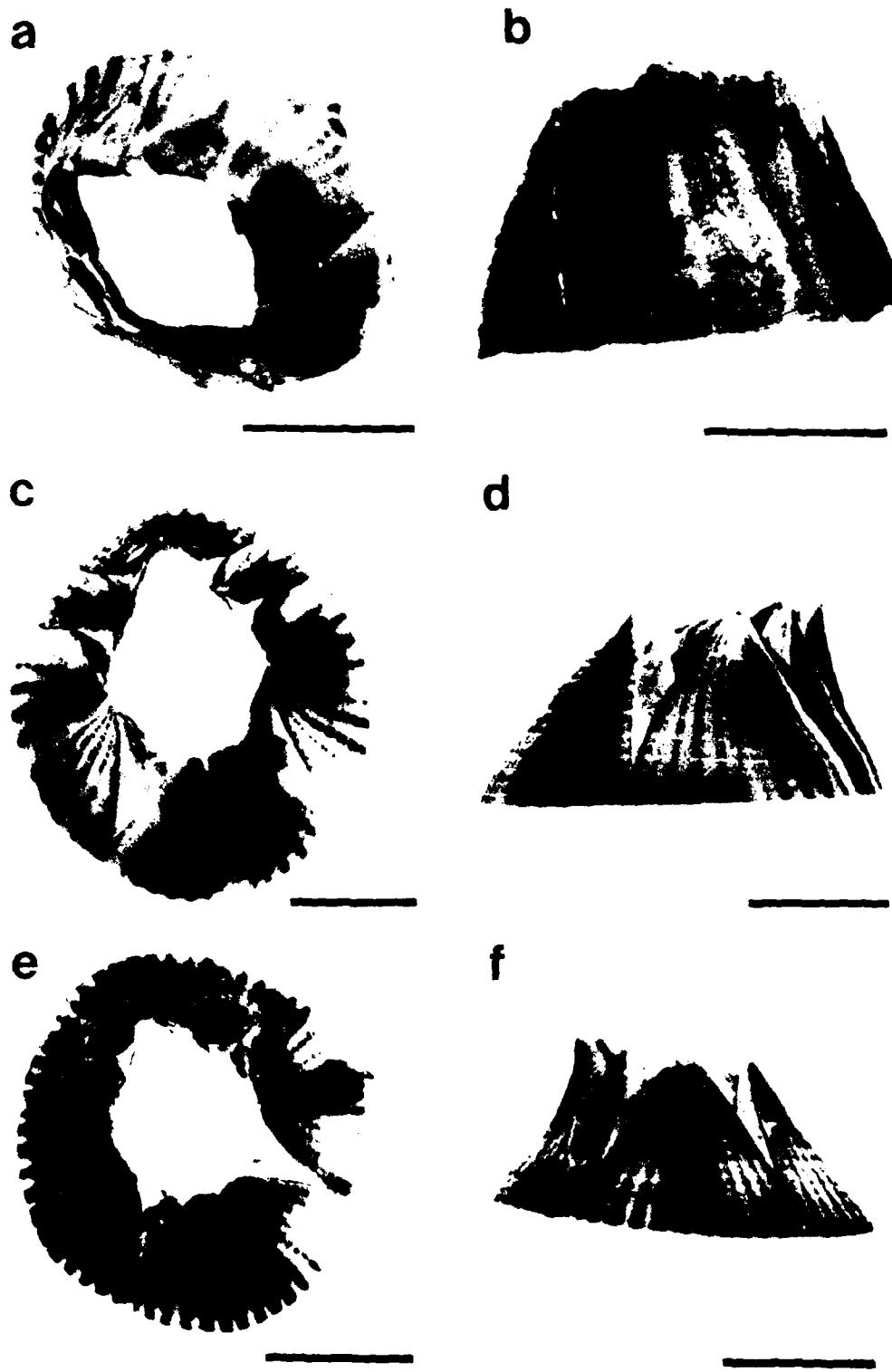


PLATE 3 Surface and lateral view of outer shells
a, b. *Balanus amphitrite amphitrite*
c, d. *Balanus reticulatus*, colour form 1
e, f. *Balanus reticulatus*, colour form 2
(Scale bars = 5 mm)

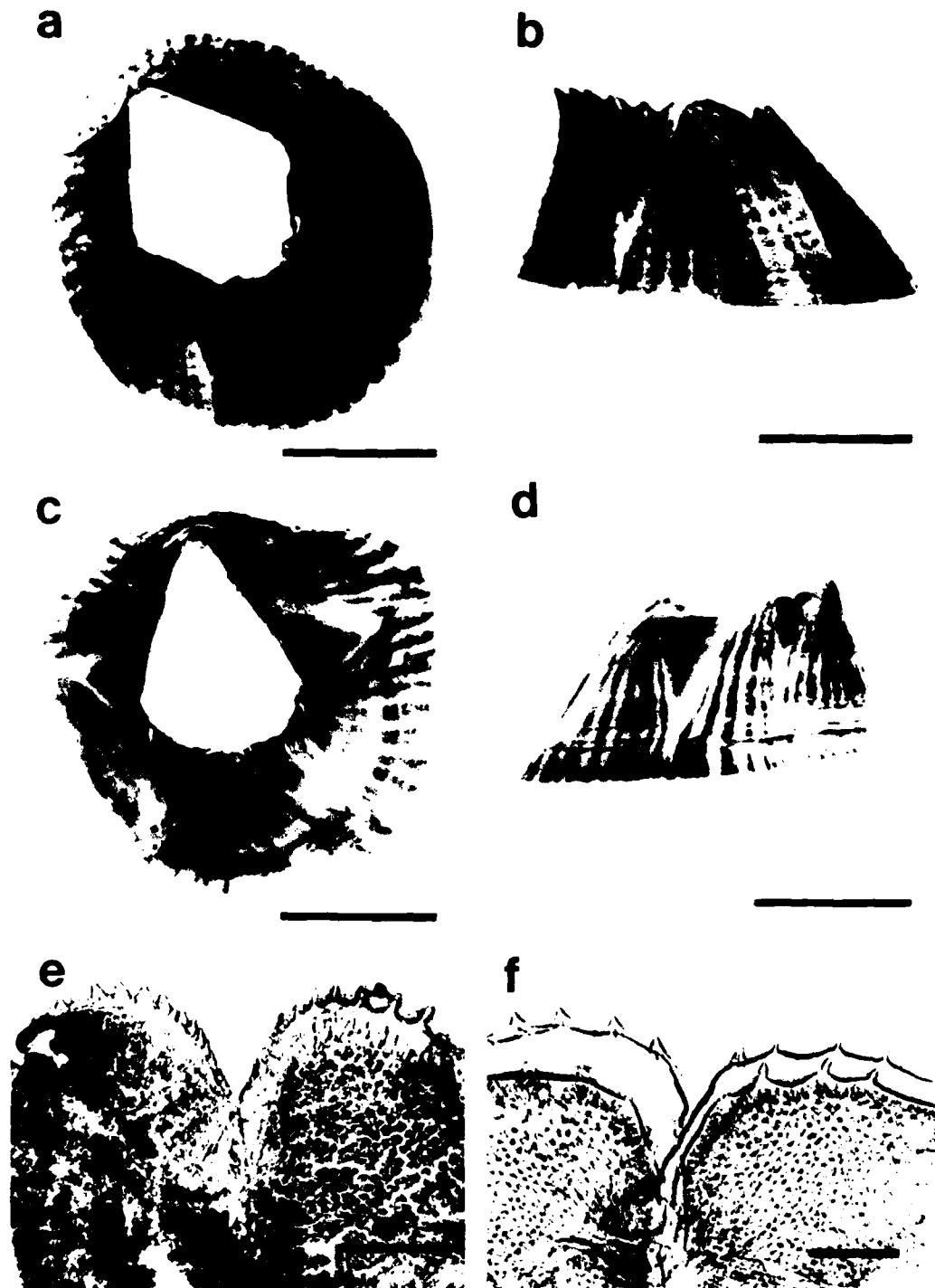


PLATE 4 a-d, Surface and lateral view of outer shells

a, b. *Balanus variegatus*

c, d. *Balanus trigonus*

e-f, Labra

e. *Balanus amphitrite amphitrite*

f. *Balanus reticulatus*

(Scale bars a-d, 5 mm; e-f, 0.1 mm)

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